moisture-laden air causes heavy rains. A case in point is high pressure in the vicinity of Bermuda, accompanied as it is, with warm weather and a quiet inflow of moist oceanic air over a large part of the Southeastern States, including Georgia. Of course, the convective rains usually are of short duration, but sometimes the same pressure relation is maintained for several days at a time, and heavy rains occur in the same locality for 2 or more days in succession.

Convective rains are frequent in southern Georgia during the summer months, July and August, especially. At Blakely, Quitman, and Brunswick in southern Georgia the July normal rainfall amounts are 7.22, 7.28, and 7.16 inches, respectively. Some of this precipitation undoubtedly is due to tropical storms, but the rains occasioned by thundershowers contribute most to the great July normal at these stations.

The official in charge of river work in Georgia should note the conditions that may produce heavy rains in the State even during the summer season, for while floods are least likely to occur during the warm months, yet when heavy rains are more or less general, floods may result. Sometimes a tropical storm causes rains that flood some of the rivers in the State, or again floods may result from general thundershowers. The tropical storm of July 1916 caused general floods in Georgia, and the heavy rains in July 1919 brought floods in some rivers in the State. Rains in August 1908 and in August and September 1928 and September and October 1929 also produced flood conditions in many of the rivers in the State.

Heavy or excessive rainfall in Georgia during the winter, spring, and autumn; that is, during the period when precipitation largely is governed by cyclonic action, usually is caused by a well-developed disturbance centered near or over Georgia. The southwestern LOW, to cause excessive rains in this section, must take the southern route and must move east-northeast to the Carolinas. If there is a strong HIGH over the Atlantic States in front of the LOW, heavy rains are more probable. Similarly, disturbances that develope during the cold season in the Gulf of Mexico, especially when there is a vigorous high pressure area to the northeast, are producers of copious precipitation in Georgia. The V-shaped depression also frequently is attended by heavy rains when it moves across the State. Very heavy rains fell in Georgia during March 13–15, 1913, in connection with a storm of this type. Similarly, a trough of low pressure moving across the country, especially when there is a secondary development in the southern part of the trough, gives generous rains over much of the State. The rains of December 14 and 28–29, 1901, over much of the northern half of the State were the result of developments of this character. Sometimes a strong, well rounded cyclonic area appears over the northern Rocky Mountains and, in its eastward progress develops one or more secondary depressions well to the south of the primary one. A storm of this type produced the remarkably heavy rains of March 13–15, 1929, which resulted in either the highest or second highest river stages on record in the Chattahoochee, Flint, and Apalachicola Rivers from West Point and Montezuma, Ga., down to Blountstown, Fla.

The writer has observed in practically all instances of heavy rains in Georgia referred to in the preceding paragraph that there was a high pressure area to the east or northeast of the trough or depression. This arrangement of pressure provides a strong inflow of air over Georgia with the high vapor content necessary to produce heavy precipitation as the disturbance advances over the State.

The really heavy rains (5 inches or more within 24 hours) occur most frequently during July to October, when they are due either to convection or to the visitation of tropical cyclones, and again during the cold months, especially in February and March, when they are the result largely of extra-tropical cyclones passing over or near Georgia.[2]

The rains of outstanding magnitude, as a rule, have been those due to tropical storms, but those accompanying extra-tropical storms sometimes are not far behind, a noteworthy instance being the occurrence of 10.88 inches of rain at Blakely, Ga., on March 15, 1929. Further information on the seasonal distribution of heavy rains is contained in the following table which shows the greatest number of stations by months with prolonged heavy rains of 5 inches or more in 2 days and, for longer periods, at least 3 inches more than the number of days.

Month	Greatest number	Year	Month	Greatest number	Year
January	26	1925	July	34	1916
February	13	1929	August	14	1928
March	25	1929	September	19	1929
April	7	1912	October	19	1929
May	2	1901, 1903	November	4	1906
June	6	1902	December	21	1919

The year 1929 stands out as the year with the most frequent heavy rains.

[2] See preceding paper by Mindling.

REMARKS ON THE THEORY OF THE PSYCHROMETER

By W. J. HUMPHREYS

[Weather Bureau, Washington, November 1933]

The validity of the classical theory of the psychrometer is now and again questioned and a substitute offered that is far more elaborate than that which hitherto has been considered adequate. As the older theory is very simple, and also, some of us hold, entirely sufficient, it may be worth while to tell it again, with a little variation, perhaps, in the interest of simplicity and clearness.

The psychrometer, an instrument used for determining the humidity of the air, consists, in part, of an adequately ventilated thermometer whose bulb and adjacent portion of the stem are covered with a closely fitting jacket, commonly of clean, unstarched muslin, that is kept fully wet with pure water, but generally not dripping. Its gain of heat through conduction along the stem and by radiation are negligible in comparison with that by contact with the free air (made so by construction and manipulation), or approximately known and allowed for. In short, such gains of heat by the wet-bulb thermometer may be regarded as zero, since with a good instrument properly used they are, for most purposes, negligibly small, and since, whenever necessary, their values can be determined fairly closely and applied as corrections.

In many psychrometers one side of the wet bulb continuously faces the ventilating and more or less smoothly flowing current while the other side is exposed to the turbulent wake in this current produced by the obstructing instrument. This irregularity must, it would seem, affect the temperature of the wet bulb, but experiment shows that the extent to which it is thus affected is imperceptible when the ventilation is vigorous. Besides, the psychrometer can be so constructed and operated that all parts of the wet bulb are equally and abundantly ventilated.

It will be assumed, therefore, that the wet bulb is uniformly ventilated all over and that we have only to consider its loss of heat through evaporation and its simultaneous gain of heat through contact with the surrounding air. Obviously, these two quantities, heat loss and heat gain per minute, say, or other time interval, are equal when the temperature of the wet bulb remains constant.

Under the above restrictions as to radiation and stem conduction it is clear that heat can be given to the wet bulb by the warmer surrounding air only by conduction (in this case molecular diffusion) or convection (mass diffusion). In both cases the transfer of heat is by contact, and the only difference is in the rate of action. In general convection is much speedier than diffusion.

When a steady state is reached it may be assumed that the shell of air of exceedingly minute thickness, one thousandth of an inch, say (much thinner, if we wish, as that still is 100 times the molecular free path in air of sea-level pressure and room temperature), has the temperature of the wet bulb, and that the space occupied by this shell is saturated with water vapor, of course at this same temperature. Accordingly there always is a vapor pressure gradient to or from the wet bulb, except when the space round about is saturated with water vapor, in which case the temperature of the wet bulb is the same as that of the free air. Let there be a vapor-pressure gradient outward, as usually is the case. There then will be a continuous flow of vapor out from the space in question, tending to reduce its humidity to below saturation and an equally rapid evaporation to maintain saturation, which evaporation consumes heat and tends to lower the temperature of the wet bulb. Thus where there is a vapor gradient outward there is a temperature gradient inward. Also experiment shows that, under the given conditions, the temperature of the wet bulb soon comes to a constant value, more or less below that of the free air. That means that the supply of heat to it from this warmer air, no matter how it arrives, is at exactly the same rate as the loss of heat by evaporation. In other words, the net loss or gain of heat by the wet bulb is zero, and therefore its temperature remains unchanged.

Let, then, the net evaporation (evaporation minus condensation) of water from the wet bulb in a given interval during the time of the "steady state" be n molecules. The heat thus lost is given by the equation

$$Q = nw'L_{t'}$$

where w' is the mass of a molecule of water vapor and $L_{t'}$ the latent heat of vaporization at the temperature t' of the wet bulb.

As explained, exactly this same amount of heat must somehow be supplied to the wet bulb from the free air whose higher temperature is t. This could be supplied by the cooling of a certain number N of the air molecules from their initial temperature t to that of the wet bulb, t', or, in symbols,

$$Q = Nws(t-t')$$

where w is the equivalent mass per molecule of the free air mixture of gases (mass of a given volume of this air divided by the number of molecules in that volume) and s the specific heat of this mixture.

From these two equations we get

$$n = \frac{Ns(t-t')}{\frac{w'}{w}L_{t'}} \tag{1}$$

As previously stated, all the cooling obviously is at the surface of the wet bulb by the evaporation, in a given time, of n molecules of water, and all the sustaining, incoming heat delivered also at this surface in amount equal, in the same time, to the cooling of N molecules of the free air from its temperature t to t', or would be if the supply of heat to the wet bulb were direct from the free air as here indicated. If this supply of heat is not direct it then must be through a step by step process in which some of the outer air is cooled by a less amount than $t-t'$, while the colder air that gains this heat is warmed to a correspondingly higher temperature, and thus rendered more effective in its transmission in turn of heat towards, or to, the wet bulb. Presumably, therefore, the final result would be the same in either case however different the times of its attainment. And this conclusion is supported by the fact that the end temperature of the wet bulb is the same for all degrees or speeds of ventilation so far tested (a wide range), when radiation and other disturbing factors, here supposed absent, are excluded or properly allowed for.

Also, when the temperature and pressure are constant, every small volume of the gas adjacent to the wet bulb that is torn away is replaced by an exactly equal volume, when at the same temperature, of the free air. And as the cooling is by the evaporation of the extra water molecules thus removed while the heating is by the warmer air simultaneously brought in, it follows that, for any particular temperature, t', say, the number, n', of molecules of evaporated water in this minute volume of evicted saturated air is given by the equation

$$n' = k\frac{e''}{B},$$

and the number, N', of those of the substituted free air by the equation

$$N' = k\frac{B-e''}{B}$$

where B is the total barometric pressure, e'' the pressure due to the freshly evaporated water, and k the number of gas molecules per volume equal to that under consideration at the temperature t' and pressure B. But when the temperature and pressure are constant the value of k is the same for all gases and mixtures of gases, hence it has the same value in the above equations.

Furthermore, since these equations apply to each and every exchange between the cooler saturated air adjacent to the wet bulb and the warmer free air, it follows that they hold also for our original n and N, that is, the total number, respectively, of the evaporated water molecules evicted from around the wet bulb in a given interval of time and of the free air molecules simultaneously brought in and by which the steady temperature of the wet bulb is maintained. Therefore, substituting our original n and N for the n' and N' in the above equations, dividing one by the other, and noting that the value of k is the same in each, we get

$$\begin{aligned} n &= N\frac{e''}{B}\left\{1+\frac{e''}{B}+\left(\frac{e''}{B}\right)^2+\text{-------}\right\} \\ &= N\frac{e''}{B}D \end{aligned}$$

Substituting in (1), we have

$$e''=\frac{Bs(t-t')}{\frac{w'}{w}DL_{t'}}$$

But $e''=e'-e$

where e' is the vapor pressure corresponding to saturation at the temperature t' and e the vapor pressure of the free air, the thing we are trying to evaluate.

Therefore

$$e=e'-\frac{Bs(t-t')}{\frac{w'}{w}DL_{t'}}$$

But as e is only a small fraction of B it follows that s is nearly the same as the specific heat, and w' approximately the equivalent molecular weight, of absolutely dry air and D a number but little greater than unity. We may therefore assume these limiting values for s, w' and D, and obtain the first approximation to the value of e. We then can correspondingly correct s, w' and D and find a closer value of e, and so on as far as we wish to go. Usually, however, the first approximation to the value of e is (theoretically) correct to less than 1 percent.

Therefore, closely enough for most purposes,

$$e=e'-AB(t-t')$$

where A is a numerical constant, of one value when the wet bulb is covered with liquid water and another when the coating is ice.

THE COLD POLE OF SOUTH AMERICA

By JULIO BUSTOS NAVARRETE, Director

[Observatorio del Salto, Santiago, Chile, October 1933]

(Translated by W. W. Reed)

On account of its geographic configuration, being surrounded by great oceans, South America does not offer conditions favorable for the occurrence of intensely cold weather such as is experienced in Siberia and North America. Nevertheless, the investigations made during 14 years by the Observatorio del Salto have shown that in South America, as in other regions, there exists a cold pole, which is well defined and from which there radiate cold waves every winter.

One naturally would suppose that the most intensely cold weather in South America occurs in Magallanes, the most southerly portion of the continent, but this is not the case. The observations made during many years at stations in Chile and Argentina have shown that the most intense cold occurs in a small zone situated in the interior of the continent, the region limited by the stations of Chos Malal, Lonquimay, Las Lajas, and Bariloche.

The occurrences of very low temperatures are always accompanied by mighty invasions of polar air loosed from the Antarctic front. These enormous air masses, indicated on the meteorological charts by anticyclonic systems of high pressure, often enter the continent between latitudes 40° and 50° S., lingering at times in the region of Aysen, Chiloe, and Llanquihue on account of the natural resistance offered to their advance by the cordillera of the Andes.

Under these conditions the anticyclonic centers usually remain for several days or even weeks over southern Chile, bringing generally fine weather with south or southwest winds, which keep the air clear during the long winter nights. Such meteorological conditions are extraordinarily favorable to rapid loss of heat at night by radiation. The land quickly loses its accumulated heat and for several consecutive nights the minimum temperatures in the open fall gradually and progressively. The masses of cold polar air and their calm and transparency during the long winter nights all favor the loss of heat from the earth. The snow is changed into compact ice, which the feeble rays of the sun of the next day are unable to melt. Hence it accumulates, layer upon layer, after each nocturnal freezing brought by an invasion of polar air.

For these reasons there have occurred in the region bounded by Chos Malal, Las Lajas, Lonquimay, and Bariloche minimum temperatures of −32° C. in standard shelters and −40° C. in the open with clear sky. This zone constitutes what is known as the cold pole of South America, and from this region there radiate the cold waves that in severe winters often invade the central valley of Chile and the pampas of Argentina.

As the cold pole in our hemisphere is always situated northeast of the center of high atmospheric pressure, or anticyclone, the diverging waves of icy air spread low temperatures to the remainder of the southern part of the continent. On the meteorological charts of South America it is possible to follow, day by day, the advance of these waves of cold air that moderate little by little until they reach the equatorial regions.

AN AID IN LOCATING AND STUDYING CLOUDS

By IRVING F. HAND

[Weather Bureau, Washington, November 1933]

In studies of solar radiation, it often is essential to know whether the ever-present haze is without form, or owing in part to definite clouds. A Nicol prism mounted at the eye end of a tube (the latter to cut off extraneous light) is not only of great help in locating clouds of indefinite form, but also resolves details of an intricate kind that ordinarily would remain undetected.

The writer recently made a simple instrument of this nature and tested it with the aid of several casual observers. Filters of various colors were tried in the optical train and while theoretically red should give the best results, the consensus of opinion was that the instrument worked better without any filter. In several instances clouds were rendered visible within the area of maximum polarization that could not be seen with the naked eye.

This "cloud finder" has its limitations as shown by the theory of skylight polarization. Generally speaking, maximum polarization occurs in a plane at right angles to the direction of the incident solar rays, but the percentage decreases as we get away from a point 90° from the sun. Thus with the sun on the horizon the maximum polarization occurs in the zenith. At that point it is plane-polarized vertically, while on the horizon at right angles to the sun's direction, that is, to the north